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First record of the invasive Brown Anole, *Anolis sagrei* Duméril & Bibron, 1837 (Squamata: Iguanidae: Dactyloinae), in South America

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Abstract: We report the first record of the invasive Brown Anole, *Anolis sagrei* Duméril & Bibron, 1837, in South America based on nine specimens from Samborondón, Guayas province, Ecuador. We also present some information related to the current distribution in Ecuador, and its possible impacts on native lizard species.

Key words: Ecuador; introduced species; Guayas; lizards; distribution; urban areas; range extension

Introduced species are known to be potentially harmful and cause negative effects on native species and ecosystems. In addition, economic losses are common because of the occurrence and persistence of introduced species (Pimentel et al. 2001). Events of species introduction constitute one of the main drivers of biodiversity loss (Chapin et al. 2000; Didham et al. 2005). In some cases, non-native species constitute the cause for local or global changes in abundance, and of species composition (Kraus 2015; Nuñez & Pauchard 2010). Thus, it becomes a big challenge to counteract the advance of introduced species, especially in megadiverse countries that are undergoing intensive economic development (Lövei et al. 2012). Despite the exceptional biodiversity of South America (Myers et al. 2000), not many developing South American countries have dedicated sufficient research resources to investigate non-native species and the impact of them on local ecosystems and its biodiversity (Speziale et al. 2012). Examples of introduced species that have caused serious impacts on the native biodiversity of South America are North American Beaver (*Castor canadensis*) in Chile and Argentina [see Wallem et al. (2007) and Anderson et al. (2009)], Chinook Salmon, *Oncorhynchus tshawytscha* in Chile [Correa & Gross (2007)], and Red Swamp Crayfish, *Procambarus clarkii* in Brazil, Colombia, Ecuador, and Venezuela [Loureiro et al. (2015)].

The number of introduced species of amphibians and reptiles in the continental part of the Americas is small; these introductions have been caused mostly by human actions and cause biodiversity loss. An example is introduced populations of American Bullfrog, *Lithobates catesbeianus*, in many countries of Central and South America for the purpose of breeding on farms and trading the meat (see Valarezo-Aguilar et al. 2016). *Lithobates catesbeianus* is well known for its large size and voracious appetite, and preys on several native species, displacing even other amphibian native species (Laufer et al. 2008; Akmentins et al. 2009). Other examples of introduced species of herpetofauna were analyzed by Hegan (2014) (e.g., Burmese Python, *Python bivitattus*; Cuban Brown Anole, *Anolis sagrei*; Cuban Treefrog, *Osteopilus septentrionalis*; Green Iguana, *Iguana iguana*; Mediterranean House Gecko, *Hemidactylus turcicus*; and Nile Monitor, *Varanus niloticus*). Nevertheless, the impacts of these introductions have been mainly on native species of flora and fauna, displacing or predating them.

At a global scale, several lizard species of the genus *Anolis* have been found, reported and studied in hundreds of places outside their natural range (e.g., Nicholson & Richards 2011; Stuart et al. 2012; Norval et al. 2014; Yasumiba et al. 2016). For example, the Cuban *Anolis porcatus* was reported recently by Samelo & Barrela (2016) in São Paulo state, Brazil. Prates et al. (2016) realized its molecular identification and geographic origin and suggested that *A. porcatus* reached Brazil unintentionally via transportation on ships.

A classic successful example of a non-native species of *Anolis* is the case of *A. sagrei*. Duméril & Bibron (1837) described *A. sagrei* from its original location “Cuba”. Its

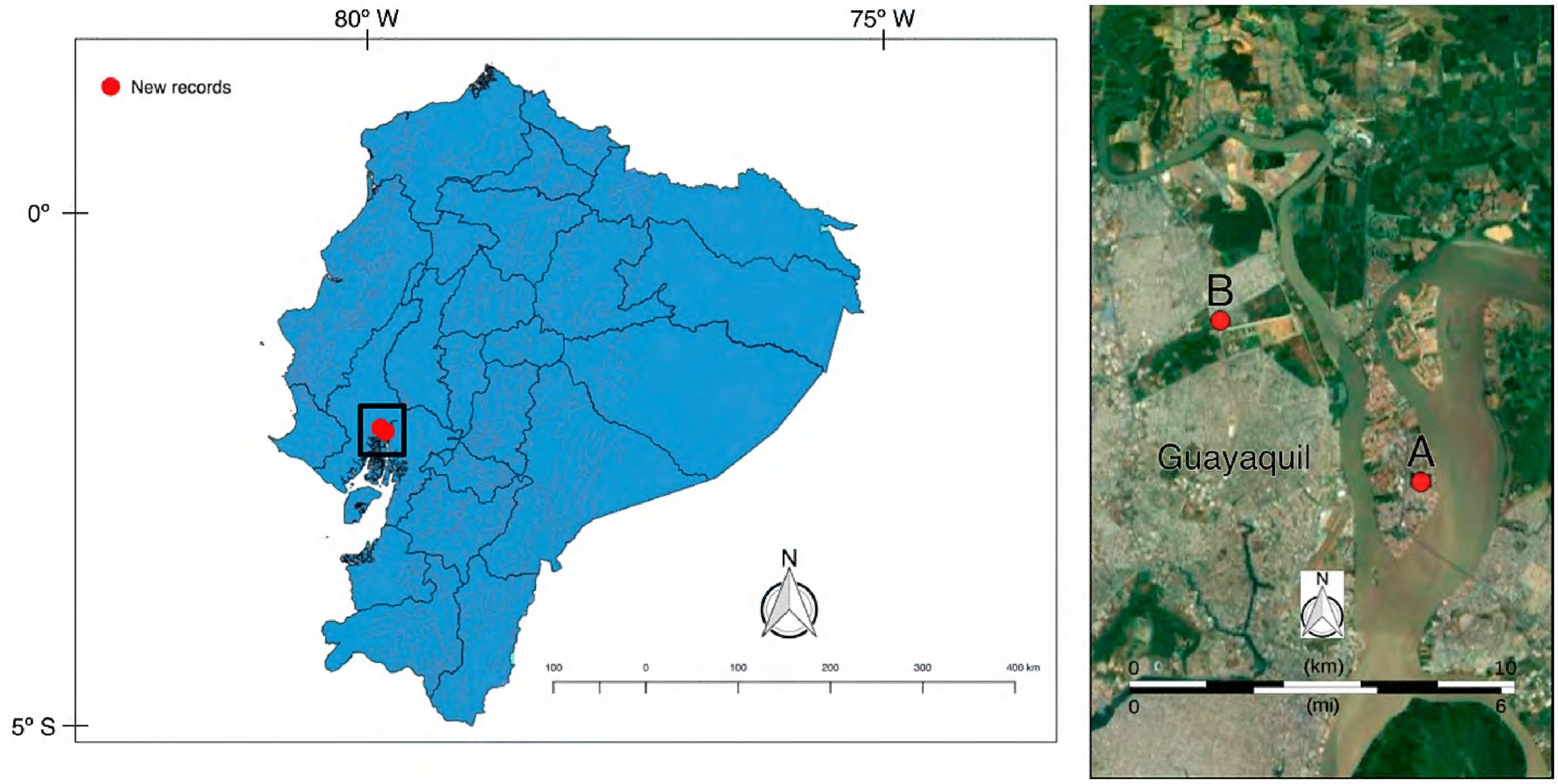

Figure 1. Distribution of *Anolis sagrei* in Ecuador (red circles). The box shows the two new records in Guayas province. **A.** Parque Histórico of Guayaquil (PHG). **B.** El Cóndor town, near Parque Samanes.

native range also includes the Bahamas, the Caribbean coast of Mexico (Losos J.B. personal communication), Little Cayman, Cayman Brac, other adjacent little cays, and satellite islands in the Caribbean. This species, commonly known as the Brown Anole, was recognized as an invasive species in 1887, when it was found in Florida, USA (Granatosky & Krysko 2013). It is currently reported in 12 other states in that country, including the mid-Pacific state of Hawaii (Mautz & Shaffer 2011; Granatosky & Krysko 2013). In Central America, the Brown Anole has also invaded the Mexican interior, Belize, Bermuda and several Caribbean islands such as Grand Cayman, Grenada, Turks and Caicos and Anguilla (Greene et al. 2002; Kolbe et al. 2004; Burgess 2012; Williams & Carter 2015; Stroud et al. 2017). Introductions in Jamaica could have been mediated by humans (Burgess 2012). However, this assumption remains unclear. Furthermore, *A. sagrei* is introduced to Asia, where it is known from Taiwan (Norval et al. 2002), and more recently, Singapore (Tan & Lim 2012).

Previous phylogenetic studies on introduced and native populations of *A. sagrei* have shown that several dispersal events between native localities and invaded areas are possible (Kolbe et al. 2004; Kolbe et al. 2008). These events are caused mainly by anthropogenic activities, such as the pet trade, ornamental plant trade, and tourism (Powell et al. 2011; Tan & Lim 2012). Herein, we report for the first time the occurrence of *A. sagrei* in South America, based on records from Ecuador. It is noteworthy that this record is the first in the southern hemisphere. All previous records were reported in the Tropical Atlantic and Central/Eastern Indo-Pacific area, including natural localities and the invaded areas (Norval et al 2002; Mautz & Shaffer 2011; Toscano-Flores & Calzada-Arciniega 2015; Williams & Carter 2015).

We collected individuals of Brown Anoles at Parque Histórico de Guayaquil (PHG) (Figure 1), a recreational tourism park in an urban area of Samborondón, province of Guayas (02°08′39″ S, 079°52′12″ W, 7 m). It is managed by the central government of Ecuador. On 18 December 2015 during a 1-hour survey (10:30–11:30 h), we observed 25 individuals (males, females, juveniles and neonates) within an area of 16 m^2 at PHG. Of these, six individuals were collected, two adult females (QCAZ 14296-97; Figure 3) and four juvenile specimens (QCAZ 14298-99, 14300-01), which were found perching at a height of 0.5–1.5 m on herbaceous plant species and on big trees such as *Triplaris cumingiana* at a height of 2–4 m (Figure 2). On 11 February 2016 (10:00–12:00 h) two additional specimens were collected, one subadult female (QCAZR 14489) and one juvenile male (QCAZR 14490) from the same area and with similar activity as the six previously mentioned individuals. All specimens were found in a garden that surrounds an artificial island, and along streets near PHG. The garden vegetation was dominated by a mixture of native species with introduced species of herbaceous and ornamental plants, mostly *Calathea* sp., *Crinum* sp., *Alpinia* sp., *Anthurium* spp., which do not represent any natural ecosystem. On 11 February 2016, one adult male (QCAZR 14488; Figure 3) was collected from a ficus tree (*Ficus benjamina*) on the street 495 m away from the locality at PHG. Two additional individuals (not collected) were found inside a house near "Parque Samanes" in northern Guayaquil (02°06′41″ S, 079°54′24″ W, 10 m) 5.5 km in a straight line from PHG. The specimens were collected under permit 003-15 IC-FAU-DNB/MA and were deposited at Museo de Zoología (QCAZ), Pontificia Universidad Católica del Ecuador.

We also observed that males of *A. sagrei* in PHG extended their dewlap, which may suggest that males had estab-

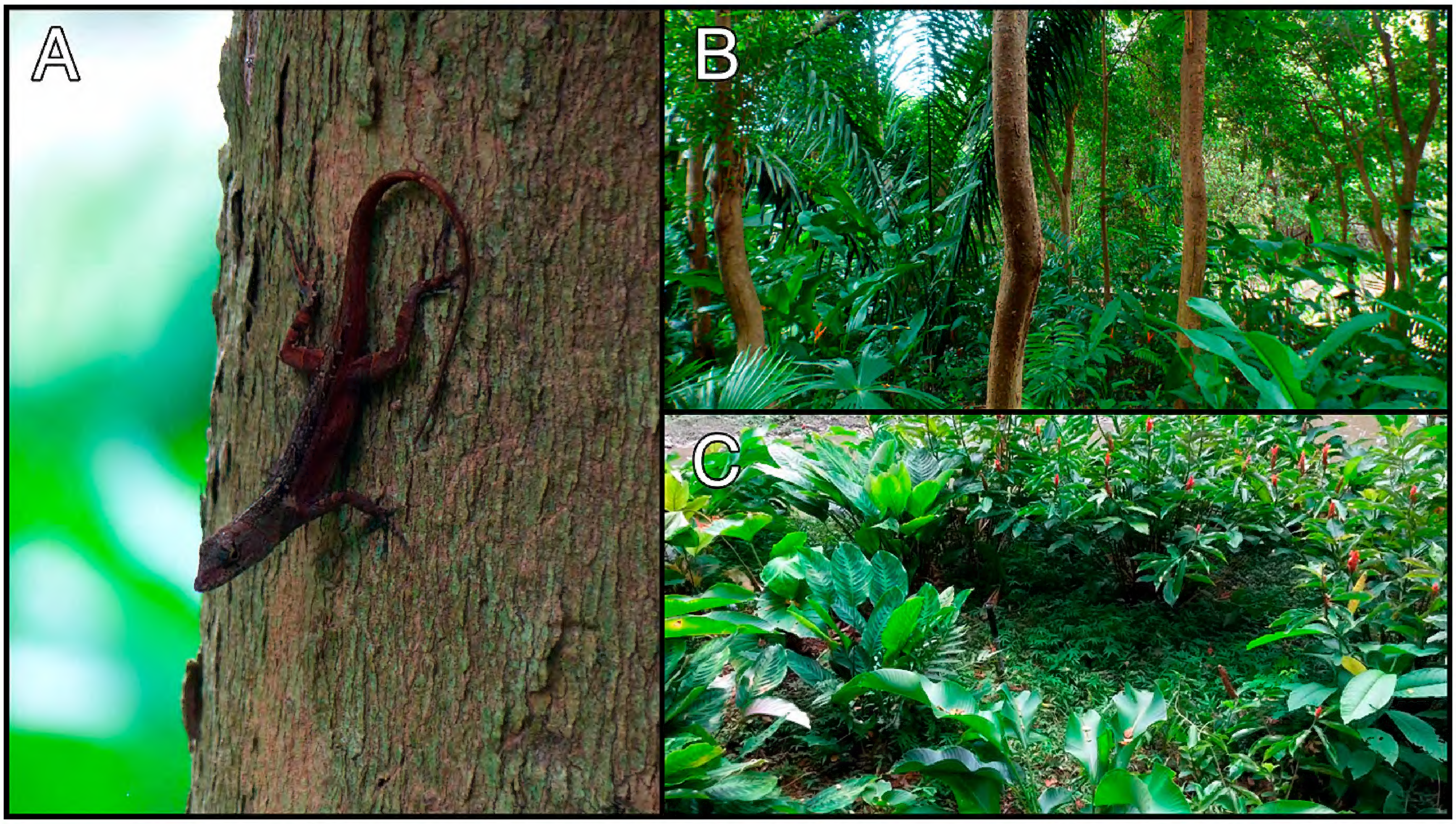

Figure 2. Habitat where *Anolis sagrei* was found in the Parque Histórico de Guayaquil, Samborondón, Guayas province, Ecuador. **A.** Individual of *A. sagrei* not collected. **B.** Habitat of native and non-native large trees. **C.** Habitat of native and non-native herbaceous and ornamental plants.

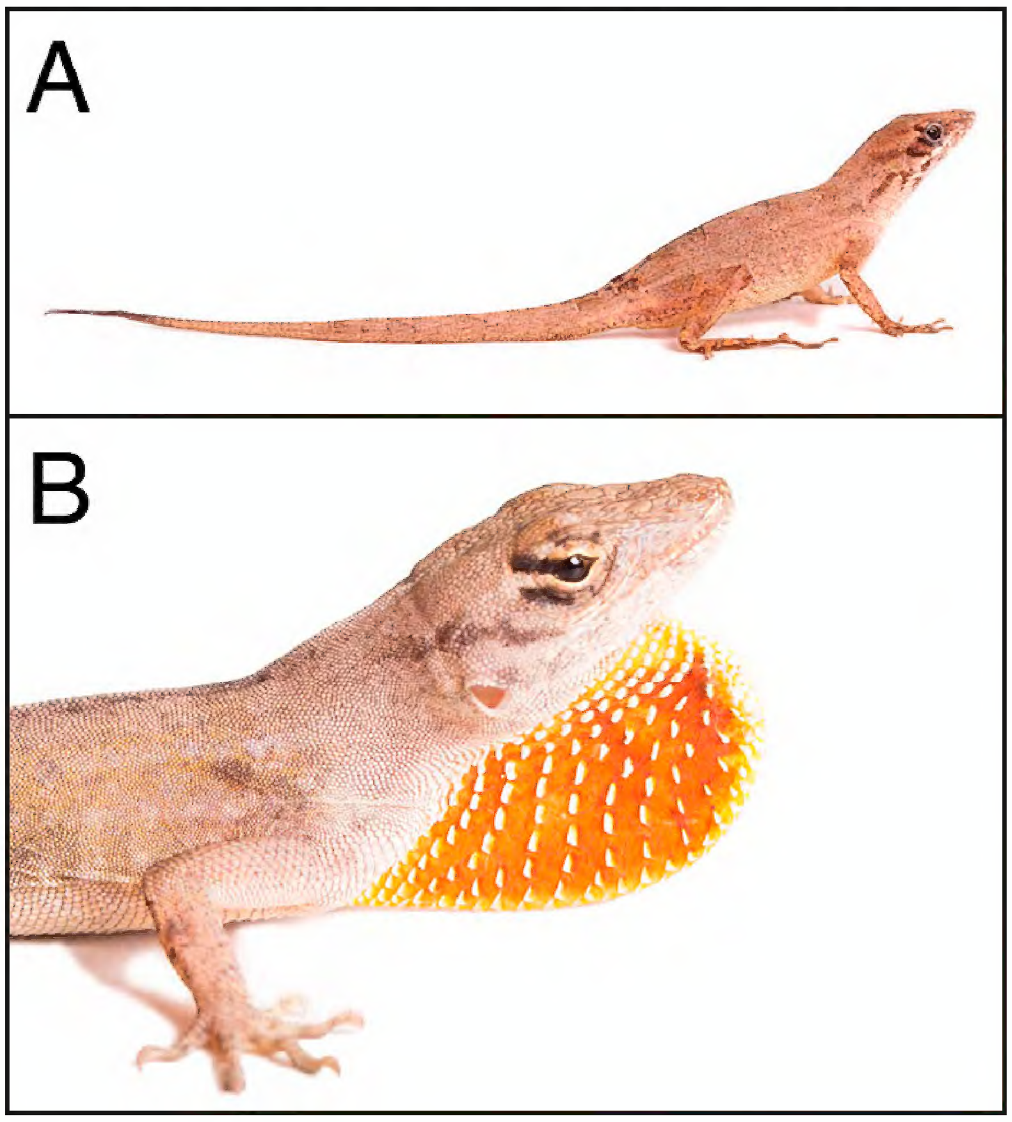

Figure 3. Two individuals of *Anolis sagrei* found in Guayas province, Ecuador. Adult female QCAZ 14296 (**A**), adult male QCAZR 14488 (**B**). Photos: Fernando Ayala and Valeria Chasiluisa.

lished territories.

New record report. Occurrence records (total 140) of *A. sagrei*, were obtained from the Global Biodiversity Information Facility (GBIF) and are presented in Figure 4, including our new records.

Morphological characterization. The external character terminology follows standards established by Williams et al. (1995) and Poe & Yañez-Miranda (2008). Lamellar number was counted only on phalanges III and IV of the fourth toe; measurements were made with digital calipers on live specimens and are given in millimeters (mm) usually to the nearest 0.1 mm. Snout-vent length (SVL) was measured from the tip of the snout to the anterior edge of the cloaca (Table 1).

The collected specimens were examined and photographed. We compared the morphological characteristics of our specimens with information reported by Poe (2004); Nicholson et al. (2007); Losos (2009) & Nicholson et al. (2012) to confirm that our specimens fall into the diagnostic characteristics of *A. sagrei*. The males of *A. sagrei* are characterized by having a red-orange dewlap, sometimes with a yellow border or blotches. Females often have a dorsal pattern with diamonds, bars, or a stripe running down their back. Brown Anoles do not have a light ring around the eye or a light stripe above the front limb. Instead, they often have two dark bars above their eyes (Kolbe et al. 2014). *Anolis sagrei* is easily distinguished by a laterally compressed tail (tail rounded or slightly rounded in Ecuadorian species. The Ecuadorian specimens presented the following characteristics (Table 1): small body size (males QCAZ 14488, 14490 with snout-vent length (SVL) = 38.6–54.2 mm; females QCAZ 14296, 14297, 14489 with SVL = 42.3–43.4 mm), moderately robust, a short snout, and a long tail and claws. The dewlap of our specimens was orange

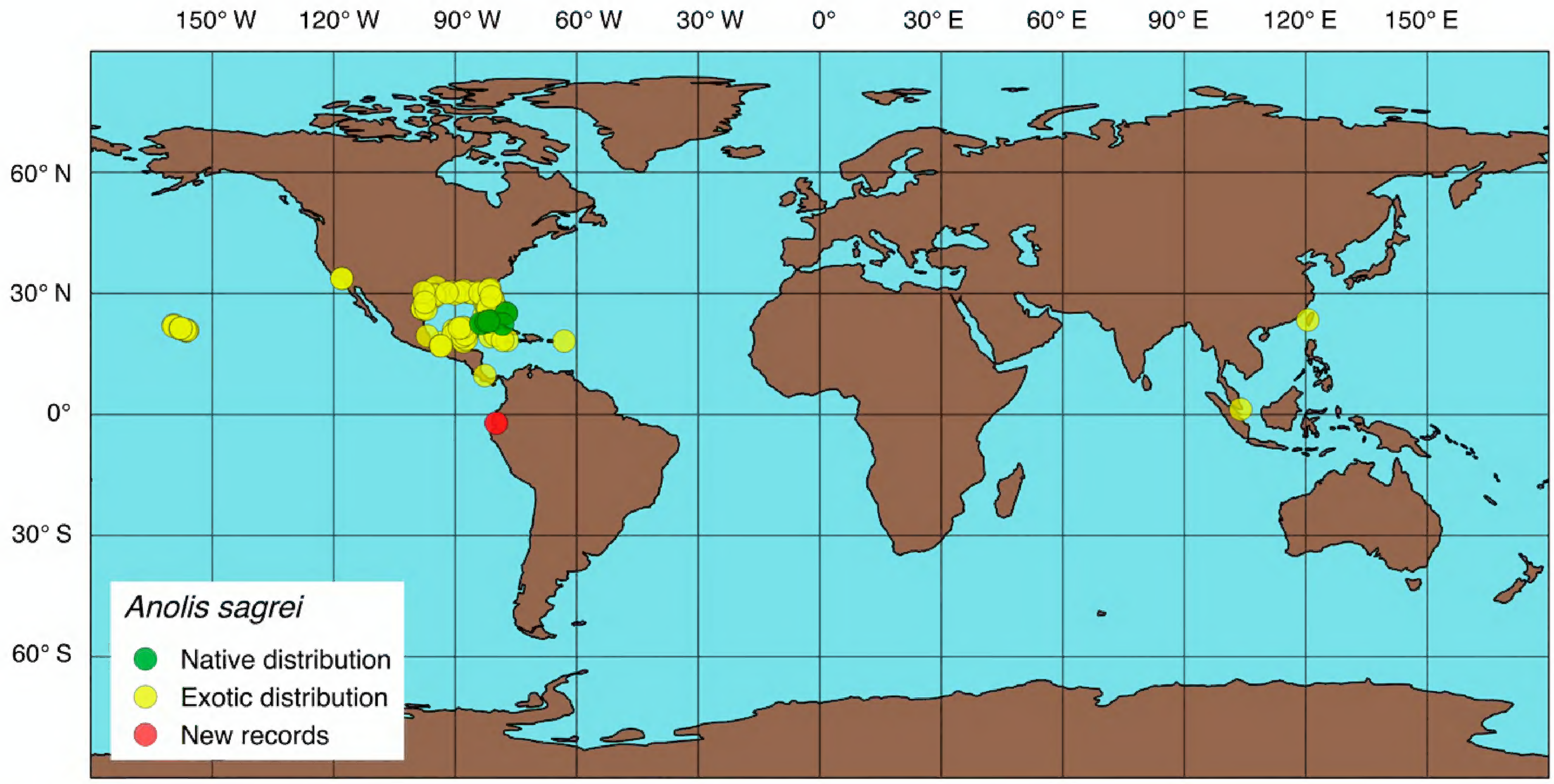

Figure 4. World map showing the locations currently known of *Anolis sagrei*. Green spots correspond to the native area, yellow spots are the non-native distribution, and the red spots corresponds to the new records reported here.

or red with yellow edges and white scales. The vent was light yellowish cream. They showed variable dorsal coloration, from a grayish-brown background with light and dark spots all over the body to an almost black background. The spots are more apparent on the face, forming dark bands on the eyes. Some specimens changed their dorsal color between grayish-brown and almost black after a few minutes of being captured. Some individuals also have a light medium dorsal line. This diagnosis agrees with the morphology presented in other areas of the native range, and with areas where the species has been introduced (Norval et al. 2002; Tan & Lim 2012). However, the number of lamellae in the fourth toe is higher than other localities (35–37, Table A1). Steven Poe from the Department of Biology at the University of New Mexico confirmed the identity of the specimens.

Anolis sagrei is the fourth species of non-native lizard successfully introduced in continental Ecuador. The three previous species correspond to two Asian geckos, *Lepidodactylus lugubris* and *Hemidactylus frenatus* (Jadin et al. 2009), and one African gecko, *Hemidactylus mabouia* (Carvajal-Campos & Torres-Carvajal 2010). We observed male and female adults, juveniles and neonates of *A. sagrei*; therefore, we conclude that there is already a well-established population in the PHG, and that this species is utilizing non-native vegetation (*Ficus* spp.) at the urban area of Samborondón, Guayas.

The specimens reported here were not found in sympatry with other native lizard species. However, this area seems suitable for the occurrence of diurnal species such as *Iguana iguana* and *Gonatodes caudiscutatus,* the nocturnal species *Phyllodactylus reissii*, and the introduced gecko *Lepidodactylus lugubris*. It is very likely that *A. sagrei* would compete with them for resources. Further observations are needed to know if other anole species are present in the PHG, and whether *A. sagrei* influences the structure of communities.

We still do not know the geographic origin, the mean of transportation, or the colonization time of this population of *A. sagrei*. Nevertheless, we hypothesize that the lizards could have come on ships from the Caribbean Sea that cross through the Panama Canal (see e.g. Muirhead et al. 2015). Molecular studies would be useful to determine the origin of Brown Anoles from Ecuador.

We recommend establishing a monitoring program of the population of Brown Anoles here reported, as well as potential introduction events, which could account for a genetically diverse biological invasion (Kolbe et al. 2004). Management and education measures are necessary to achieve the goal of minimizing the impacts of this invasion and to prevent further colonization. Eradication programs and control attempts through the extermination of well-established populations of invasive *Anolis* are a significant challenge. Such attempts have failed in Japan and in Taiwan for *Anolis carolinensis* and *A. sagrei* respectively, sometimes with severe damage to native lizard species (Ishikawa et al. 2012; Prates et al. 2016). Although the possible impacts of *A. sagrei* on the environment in Ecuador are still unknown, the fact that the Brown Anole is near areas of dense vegetation and forests means it is necessary to properly monitor *A. sagrei* and its possible dispersal and effects on native fauna.

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Table 1. Scalation and morphometric comparison of *Anolis sagrei* from different localities around the world (Norval et. al 2002). SVL max = maximum snout–vent length.

Locality	Mexico (Yucatan)	Cuba (Cardeñao and Kabama)		Honduras (San Pedro Sula)		Taiwan (Chiayi)		Ecuador (Guayaquil)	
Sex	♂	♂	♀	♂	♀	♂	♀	♂	♀
Sample	1	4	1	1	1	15	16	2	3
Interorbital scales	1	0–2	2	1	1	1–2	1–2	1	1–2
Intepariental/Interorbital scales	3–4	2–3	2–3	3	3	2–3	2–4	3–4	2–3
Loreal rows	4	4–5	5	4	4–5	4–6	4–5	4–5	4–5
Supralabials	5–6	4–6	5	4–5	4–5	5–6	4–6	5	5
Scales between second canthals	7	5–6	6	5	6	4–7	4–7	6–7	5–7
Internasal scales	7	5–7	6	6	6	5–6	4–6	6–7	6–7
Lamellae 4th. toe	33	29–33	31	32	30	29–35	28–34	35–37	35–37
Dorsal scales in 5 mm	17	10–16	19	11	14	11–17	17–25	14–21	16–18
Ventral scales in 5 mm	13	9–12	13	9	12	8–12	11–15	10–15	11–13
Head length	12.2	11.2–16.2	10.7	15.7	12.7	13–17	10.0–11.9	11.1–15.5	11.8–12.6
Tibia length	10.2	9.5–16.7	9.2	15.5	12.1	11.6–14.9	7.7–10.5	8.6–14.4	9.4–9.9
SVL	41.2	38.8–62.7	38.2	59.4	48.1	47.0–62.1	34.9–44.0	38.6–54.2	42.3–43.4

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